Pioneer 11 Saturn Encounter Mission Support

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The Pioneer 11 spacecraft will fly by the Planet Saturn in August and September 1979. The Pioneer 11 Saturn encounter activities are described, followed by the DSN plans for supporting the event.

I. Pioneer 11 Saturn Encounter Description

The Pioneer 11 spacecraft was launched on April 6, 1973, and flew by the planet Jupiter, with the closest approach on December 3, 1974. After nearly 6-1/2 years of flight, the Pioneer 11 spacecraft will have a closest approach to the planet Saturn on September 1, 1979. At that time, the spacecraft will be over 10 astronomical units from Earth, and the radio transmission will take 2 hours and 53 minutes from Earth out to the spacecraft and back to Earth again.

The near-encounter trajectory is pictured in Figs. 1 through 3 (which were provided by the JPL Pioneer Navigation Team). Figure 1 is a view of Saturn from Earth during the closest approach with the spacecraft entering from the upper left and penetrating the ring plane at the point marked "inbound descending node," which is at a distance of 2.87 Saturn radii (R_s) from the center of Saturn. The ring plane penetration is symmetrical and takes place at closest approach ±2 hours at the same distance from the center of Saturn. The 2.87-R_s distance was selected because this is the distance that Voyager 2 will have to penetrate the ring plane if it is to go on to the planet Uranus. Therefore, Pioneer 11 will provide two data points to determine whether that is a safe distance to penetrate the ring plane. Periapsis occurs at 1.36 R_s, just one-third of a radius of Saturn above the cloud tops, which is 81,426 km from the center of the planet. Periapsis passage will occur at approximately 1800 GMT, ground observed time. Figure 2 shows the trajectory in a polar view and includes the orbit of the inner moon Mimas, and the visible ring. The line marked "occultation zones" shows the location of the spacecraft as it passes into the shadow of Saturn; this location is essentially the same as the point where Earth is occulted by the planet. Notice that periapsis occurs just before enter occultation, right under the inner visible ring (referred to as the C-ring). Figure 3 is a scale drawing (except for ring thickness), of Saturn, with rings edge on, which rotates with the trajectory to show the spacecraft path with respect to the ring plane and the disk of Saturn. At the inbound and outbound crossing points, labeled "a" and "c", the spacecraft is at the distance that duplicates Voyager 2's Uranus trajectory. This will also be approximately the periapsis distance for the Voyager 2 mission. When the spacecraft passes under the outer edge of the A-ring, it will be only 2,000 km from the ring plane, while at the closest approach point, labeled "b", the spacecraft will be approximately 9,000 km below the ring plane. The ring plane penetration times of closest approach ±2 hours also corresponds to the closest distance for which it is expected that Pioneer 11 will be able to successfully image the planet. This is because the relative motion of the target body will be too great for the spin scan imaging system. However, while under the ring plane, several imaging single-spin scans of the ring plane will be performed to gain, hopefully, information about other smaller-scale features of the rings, such as smaller gaps than can be detected by Earth-based observation.

The encounter time period is defined as August 3 to October 2, 1979. In this time period, approximately 15,000 commands will be transmitted to the spacecraft, all of which will be acted upon at the time of receipt. The majority of these commands are required for the operation of the Imaging Photopolarimeter. To understand the operation of this instrument and why it requires such an extensive amount of commanding, see Ref. 1. The Earth occultation will last from closest approach to E + 79 minutes.

The imaging will exceed Earth-based resolution (which is approximately 1,200 km) at ±6 days around closest approach. The best resolution of Saturn is expected to be on the order of 80 to 100 km achieved at E ± 2 hours. The rings will fill the field of view at 39 hours before closest approach, and the disk of the planet will fill the field of view 33 hours before closest approach. The trajectory allows for good imaging after closest approach. Approximately 50 images better than Earth-based are expected, with 20 of them being before and 30 after closest approach. Several of the satellites will be observed, both in imaging and polarimetry modes, with the best target being Titan. Closest approach to Titan will be 356,000 km at 25-1/2 hours after closest approach. At this distance, the resolution is expected to be about 180 km.

II. Voyager's Expectations for the Pioneer 11 Saturn Encounter

There are several areas in which the scientists involved in the sequence planning activities of Voyager hope to benefit from the data returned by Pioneer 11. First and foremost is to determine if 2.87 R_s is a safe distance to penetrate the ring plane. If Pioneer 11 is not able to safely pass through the ring plane at this distance, it is quite likely that the Uranus option of Voyager 2 will be deleted.

There are several areas in which Voyager hopes to benefit in the general category of characterizing the fields and particle environment. Earth-based observation indicates that the fields and particle environment around Saturn is one-tenth or less as intense as it is for Jupiter; however, there is great uncertainty in the Earth-based observations. It is hoped that the Pioneer 11 data will enable the determination of the magnitude and orientation of the magnetic field around Saturn. In particular, Voyager is interested in the orientation of the magnetic equator with respect to the planet's equator in order to properly time Voyager's fields and particle roll maneuvers. These are maneuvers where the entire Voyager spacecraft is rolled in order to act as a "scan platform" for the fields and particle instruments at key times in passing through Saturn's magnetosphere. It is desired to have these roll maneuvers symetrically on either side of the magnetic equator and one right on the magnetic equator. Another item is to know whether the corotating magnetosphere of Saturn extends as far as the moon Titan. If the corotating magnetosphere extends as far as Titan, there will be a requirement to observe the magnetospheric wake behind Titan that will prevent the spacecraft from executing a roll maneuver in order to look back at Titan after closest approach to that moon. Characterizing the intensity and energy levels of the fields and particle environment will help Voyager determine what special precautions may be necessary to keep the spacecraft and its instruments safe, as well as help in determining optimum gain settings for the fields and particle instruments.

If the Pioneer 11 imaging is able to identify any unique visual features of Saturn, Voyager would use this information to refine the imaging plans. In particular, the Voyager team hopes that the Pioneer 11 imaging of Titan will enable a decrease in the uncertainties of the radius of that body. Current uncertainties in the radius of Titan are ±300 km; it is hoped that the Pioneer 11 data will reduce that uncertainty to on the order of 100 km. This would enable Voyager to produce a more efficient mosaicing plan of the moon Titan, as well as to assure the return of a limb picture with one-third as many pictures dedicated to that purpose.

Lastly, Pioneer 11's polarimetry of Saturn and its satellites may be the only polarimetry into the distant future, since this function has failed on the Voyager 1 spacecraft and may not be used on the Voyager 2 spacecraft because of the fear that the rotating filter wheels might stick in an undesirable position.

III. DSN Support Plans

Even though the Pioneer 11 Saturn encounter will involve the same level of activity as the Pioneer 10 and 11 Jupiter encounters, very limited special training on the part of the DSN is necessary to prepare for the event because it will look to the DSN very similar to the configurations and level of activity required for supporting the on-going Pioneer Venus orbital operations. The training will, therefore, concentrate on the special functions that are added to support the Saturn event.

Only a single significant implementation in addition to the configuration supplied for the Pioneer 10 and 11 Jupiter encounters was necessary for the Pioneer 11 Saturn encounter. This implementation was needed to push the telecommunications performance to the absolute limit available with current technology: necessitated by attempting a Saturn encounter with a spacecraft that was designed for the Jupiter distance. The specific implementation was the installation of low-noise S-band masers at Australia and Spain; these installations were completed on May 6, 1979. The masers give an improvement in performance of approximately 0.8 dB when operated in a diplex mode (transmit and receive simultaneously). A similar low-noise maser had already existed at the Goldstone 64-meter station. An additional implementation done on a short-term basis is the installation of a programmable receiver at Station 12 to accommodate the high doppler rates that will be experienced at the periapsis passage.

In addition, to gain additional performance for ±7 days around closest approach (which covers the time period when Earth-based resolution is exceeded for the imaging instrument), the listen-only mode will be utilized at the 64-meter sites; this will give an additional 0.7 dB performance improvement. Because of the extensive command activity required, a second smaller station will have to be scheduled with each 64-meter site for this 14-day period. The stations that will support during these 14 days are: DSSs 12 and 14 (34- and 64-meter stations at Goldstone), DSSs 44 and 43 (Honeysuckle and Tidbinbilla in Australia), and DSSs 62 and 63 (Cebreros and Robledo near Madrid, Spain).

An R&D real-time arraying system, which has been installed at Goldstone on a demonstration basis for the Voyager 2 Jupiter encounter, will be utilized for the 14 days around closest approach. This system will receive the spacecraft signal at the 64-meter site and 34-meter site simultaneously, with a microwave transmission of the 34-meter data over to the 64-meter site where the signals are automatically phase-matched and added to achieve a performance improvement that is expected to be greater than one-half a dB.

Against a Project requirement for continuous 64-meter coverage for closest approach ±30 days, the actual coverage negotiated between Voyager, Pioneer Venus, and Pioneer 11 will be 10 to 19 hours a day from 30 to 15 days before closest approach, and then continuous coverage from that point in time until 30 days after closest approach.

There will be some special training of each shift at all stations to support extensive, contingency manual commanding required for the Saturn encounter. Since the imaging sequence is executed by the receipt of real-time commands, the possibility of a loss of communications circuits or a computer outage at the Ames Research Center, where the commands originate, is covered by plans that allow uninterrupted command capability for the stations by voice instruction from Ames. The level of commanding required is much greater than is usually used for manual commanding, so practice exercises have been scheduled to cover all affected shifts.

At least two arraying tests will be scheduled to measure the actual performance improvement for the Pioneer 11 bit rate and coding type. In addition, it is expected that one or two periapsis passage training exercises will be scheduled for Goldstone and Madrid because of the complexity of the operations required during that time period. Complex receiver tuning will be necessary to maintain receivers in lock because of the high doppler rates that will be experienced. This is the reason that the programmable receiver had to be installed at Station 12 so that that station could retain its receivers in lock to support the arraying. Programmable receivers already exist at the 64-meter sites. There will also be complex requirements to support radio science experiments, and to operate the occultation data assembly equipment and associated special recording functions. Finally, to guard the supercritical data, particularly at ring plane crossing and exit occultation, an activity is underway to investigate the feasibility of utilizing the precarrier detection telemetry recovery technique that was implemented for the Pioneer Venus Multiprobe entry event; this would provide a back-up analog recording in the event receiver or telemetry system lock was lost.

Reference

1. Miller, R. B., Pioneer 10 and 11 Mission Support, in Technical Report 32-1526, Volume 16, *The Deep Space Network Progress Report*, pp. 15–21. Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1973.

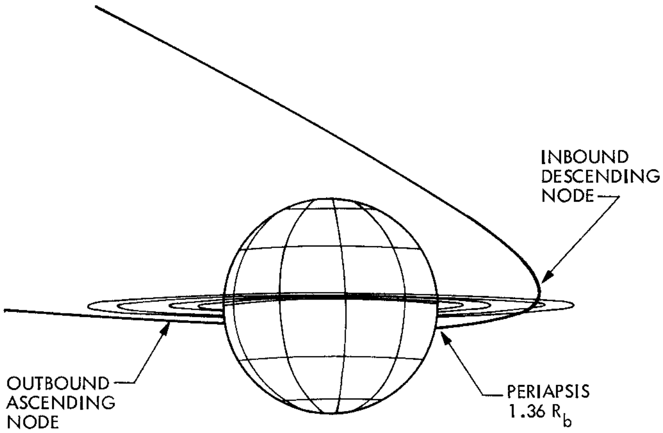


Fig. 1. Pioneer 11 Saturn flyby – balanced ring plane crossings at 2.87 R_s, view from Earth

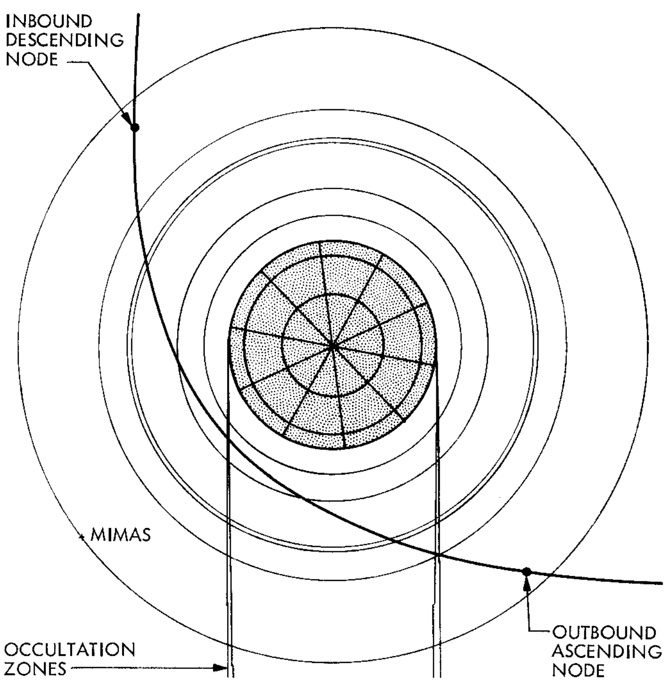
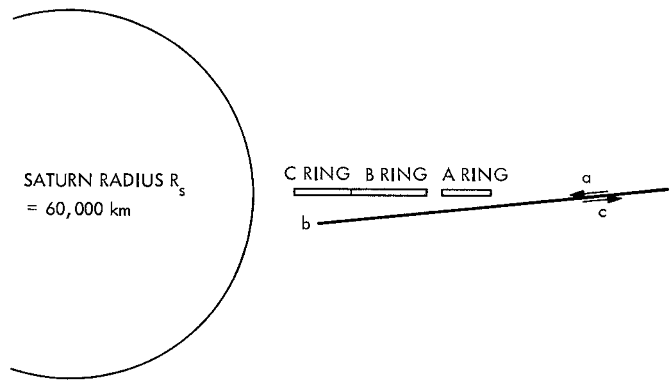


Fig. 2. Pioneer 11 Saturn flyby – balanced ring plane crossings at 2.87 R_s, north polar view



a.	INBOUND RING CROSSING	E – 2 hr	2.87 R_s*
b.	SATURN CLOSEST APPROACH	E – 0 hr	1.36 R_s
c.	OUTBOUND RING CROSSING	E + 2 hr	2.87 R_s

* (SAME AS VOYAGER JSX)

Fig. 3. Pioneer 11 Saturn trajectory in rotating equatorial coordinates